LBNL Committee Report of the Advanced Light Source Wiggler W11 Project

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Review Scope and Charge

The Femtoslicing project has received notification of funding for the project. The Femtoslicing project employs a femtosecond laser beam to interact resonantly (free-electron interaction) with the electron beam in the ALS. The induced energy spread over the femtosecond duration is converted to a transverse displacement by exploiting the dispersion of the storage ring. The displaced femtosecond electron pulse then radiates and produces femtosecond synchrotron radiation.

In order to optimize the resonant interaction the 16-cm wiggler (W16) in Straight Section 5 will be replaced by an 11-cm permanent magnet wiggler (W11). As a result of changes in DOE Basic Energy Sciences (BES) policy, essentially all aspects of synchrotron radiation research that occur behind the shielding wall (insertion devices and beamline front ends) must be paid for by operating facility, or non-research program specific funds. The Laboratory has committed to providing funding from discretionary sources to pay for the W11 insertion device.

This review is to assess the proposed approach, organization, and quality to be pursued in providing the W11 device. As Laboratory discretionary funds will be used, it is important the selected approach be as economical as possible. It is also important that it proceed as quickly as possible to allow continued research on the femtoslicing approach while the superconducting undulator, laser system and other specialized scientific equipment necessary for the next phase of the research is obtained. It is also important that disruptions of protein crystallographic research at ALS are kept to a minimum. This report presents the charge, the Committee findings, comments, recommendations and answers to the specific charge questions and reports the results and conclusions of a follow up meeting with the project on the action items.

The review committee was asked to assess during the review the overall preparedness of the project team and consider the following questions.

1. Is the proposed development plan realistic, appropriate, feasible and organized in a manner that optimizes the probability of success? Are there areas that require additional attention or consideration?

2. Has an adequate make/buy study been completed and is the proposed approach the best-suited approach to providing the W11?

3. Are there technical challenges that have not been identified or given proper attention for development?

4. Are impacts on the operating characteristics of the storage ring adequately assessed and is there a plan to resolve any remaining issues?

5. Does the proposed plan adequate minimize impacts on the protein crystallography work presently conducted at the ALS?

6. Will any residual effects on either storage ring operation or protein crystallography work be sufficiently small to be considered acceptable?

7. Are project roles and responsibilities clearly defined?

8. Is the proposed project plan complete?

9. Are the correct resources, priorities and emphasis being applied to the development?

10. Is the budget estimate comprehensive and verifiable?

11. Is the schedule estimate comprehensive and verifiable?

12. Are schedule milestones clearly identified, and are the milestones frequent enough to gauge progress?

13. Does the plan include a method for managing technical risk, budget risk, and schedule risk?

Findings and Comments

Motivation for the ALS W11 device was clearly presented and there is a well-defined project structure. The experience of ALS in producing similar devices was in great evidence and serves as a principal determination in the approach to the project.

W11 Project Approach, Budget and Schedule

More work is needed than what was presented at the review to prepare the actual bid packages for the many procurements needed for the W11. The schedule as presented may not be adequate to cover this time. The nature of the interaction to develop the subassembly responsibilities being transferred to Sumitomo was not clear to the Committee. The plan to send Bill Gath to Japan to review and consult with Sumitomo on the production of the magnetic structure is seen as very positive.

If the schedule advantage of six months of producing the W11 as modified from current ALS insertion device designs (referred to as the Internal Approach from here forward) is real, it has significant scientific advantage and clearly places the choice in favor of this approach over the procurement of a complete device from an external supplier (the External Approach). However, during the review it became clear that the protein crystallography user community is not likely to support the shutdown during the SPEAR III upgrade process. Confronted with this aspect, and without information to the contrary, the Committee felt obligated to assume that a delay in projected installation until after SPEAR-III becomes available to users would be likely. In such a case, the schedule advantage of the Internal Approach is diminished and less obvious.

The project team had approached and gotten budgetary costs and schedules from the external suppliers of complete wiggler systems. However, there was no indication that any negotiation or follow up contacts with these suppliers had been pursued in order to ascertain the degree of flexibility in those budgetary estimates of cost or schedule or to fully clarify the technical aspects and limitations that each external supplier might be assuming or imposing.

The shutdown for the wiggler installation should only be about 3 weeks over a 9-month period. However, the Committee felt that the protein crystallography (PX) line could be down as much as total of 4-5 weeks without any noticeable benefit to the users such as increase of flux. A large number of (PX) users are from private industry. Consequently, the Committee suggests that if possible, the ALS look towards Spring 2004 for installation. Such a delay also provides schedule relief to the intermediate project milestones. The Committee felt that the schedule as presented had little float and was quite aggressive.

Project plan: writing of specifications can be difficult and time consuming; these activities may not be included in the present estimate.

The detail of the budget estimate as presented was lighter than what the Committee would have liked to see. Consequently, there is some concern that the uncertainties in the budget numbers may be larger than the contingency allocated would indicate.

Schedule contingency should be explicitly put at the end of the project and must not be distributed throughout.

There is no travel in the budget at present; it will be needed and should be included in a revised estimate.

Not enough engineering support during the installation and survey has been included in the budget.

Either building in-house or buying outside is adequate. There should be a strong reason not to buy externally. Wigglers are presently at a commodity level. A strong justification for the in-house option was not presented.

There may be need for additional measurements on a completed structure for a purchased device; this should be indicated in the budget and schedule.

Magnetic Design and Storage Ring Impact

The magnetic field calculations seem appropriate though preliminary as presented.

Overall magnetic requirements have been specified and well documented and justified. The W11 device will be used in an FEL interaction fashion for the Femtoslicing program and so internal trajectory specifications are also required.

If the necessary internal trajectory requirements are stringent, there should be a program of development and practice of the tuning/shimming techniques. In consideration of the tuning of the trajectory it is also necessary to examine internal steering errors that can also give rise to loss of FEL interaction through angle variations as well as the trajectory. In other words, steering errors must be corrected as closely to where they occur as possible.

The width of the poles has not been looked at in detail, but the values appear adequate. In looking over the transverse field roll-off, significant *dynamic multipoles* are starting to appear and so the Committee feels it would be inadvisable to make the poles much narrower. The Committee would like to see an additional simulation with a roll-off greater than 6 m^{-1} in order to demonstrate an adequate design safety margin.

The Committee would like to see further work with the tracking code pursued. It is suggested that an a 3rd harmonic in the field be included as well as some additional exercising of the codes to provide benchmarking.

There was no presentation as to the impact on overall ring impedance and effects from the new vacuum chamber. No problems are anticipated aside from the need to include transition pieces in the vacuum chamber design. Such transitions are likely already present.

The Committee felt that the accelerator physics investigations on the impact of the proposed device on the ALS ring may have been minimal, but may be likely adequate if the Internal Approach is pursued.

Impact on Protein Crystallography Beamline:

There appears to be only marginal gain from the perspective of the PX users. In terms of residual effects it is advisable that there should be some fallback option. This is especially important if, for some unforeseen circumstance, there is a severe impact on flux. One such fallback, for example, would be to keep the W16 device available to reinstall until it is clearly demonstrated that the PX beamline operation has not been

compromised. Keeping the W16 device in this way would provide good insurance against a major problem. Once the performance of the PX lines with the W11 has been demonstrated to reliably provide equal performance to that of the W16, the W16 device would not need to be held in reserve.

There is still need for additional development on attaching the edge of the carbon filters to their copper frames. The cost of this development may not be included in the present estimate.

Responses to Specific Review Questions:

1. **Q:** Is the proposed development plan realistic, appropriate, feasible and organized in a manner that optimizes the probability of success? Are there areas that require additional attention or consideration?
   A: Budget and schedule as presented appear light on contingency with respect to the uncertainties perceived by the Committee.

2. **Q:** Has an adequate make/buy study been completed and is the proposed approach the most economical and timely approach to providing the W11?
   A: Based on the information presented, the solutions appear equivalent. Regardless of the selected approach, we suggest the requirement that it must allow for the reinstallation of W16 for a worst-case situation.

3. **Q:** Are there technical challenges that have not been identified or given proper attention for development?
   A: See comments above.

4. **Q:** Are impacts on the operating characteristics of the storage ring adequately assessed and is there a plan to resolve any remaining issues?
   A: See comments above.

5. **Q:** Does the proposed plan adequately minimize impacts on the protein crystallography work presently conducted at the ALS?
   A: If the installation window is delayed, the impact on the scientific program should be palatable to the PX community.

6. **Q:** Will any residual effects on either storage ring operation or protein crystallography work be sufficiently small to be considered acceptable?
   A: The residual effects appear acceptable.

7. **Q:** Are project roles and responsibilities clearly defined?
   A: Yes.

8. **Q:** Is the proposed project plan complete?
   A: Subject to the caveats above.

9. **Q:** Are the correct resources, priorities and emphasis being applied to the development?
   A: The EDI appears light for the Internal Approach.

10. **Q:** Is the budget estimate comprehensive and verifiable?
    A: See notes above. The budget at present does not appear verifiable by the Committee.

11. **Q:** Is the schedule estimate comprehensive and verifiable?
    A: See schedule comments above.

12. **Q:** Are schedule milestones clearly identified, and are the milestones frequent enough to gauge progress?
    A: For a Fall 2003 installation the desire for a "go/no go" decision would be January or February 2003; sufficient information may not be present to make an adequate decision for a shutdown at that point.

13. **Q:** Does the plan include a method for managing technical risk, budget risk, and schedule risk?
    A: Technical risk seems to have been addressed, but budget and schedule risks appear significant.

Action Items

The following action items based on the findings and comments of the Committee need attention by the ALS W11 Project Team. A follow-up meeting to assess the status of the action items is to occur no later than 13 December 2002. An addendum prepared by the Committee chair will report on the progress of the action items at that time.

1. The make/buy analysis needs to be completed or assembled to allow a fully informed decision. The pros and cons of both options should be detailed and the attendant risks determined. The make/buy analysis should then be presented to the ALS Management for concurrence of the final decision.

2. The estimate associated with the Internal Option should be strengthened. Specifically, the following should be developed and provided for review by the Committee Chair and an appropriate subset of the Review Committee:
   a. The EDI cost requires additional documentation including a drawing list indicating the status of all drawings. EDI costs should separate design/drawing modification from fabrication coordination and magnetic measurements effort.
   b. The drawing package for the new magnetic pole assembly and the vendor budgetary quote and draft procurement specifications.
   c. Vendor quotes (budgetary are acceptable) for the vacuum chamber, top and bottom sections, the magnetic structure backing beams, and any of the large, or most significant support frame pieces that will be procured from the outside.

d. Updated shops estimate for the support frame.
e. Updated item-by-item contingency/risk assessment.
f. Travel and other support expenses clearly identified.

3. An additional simulation should be conducted with a roll off greater than the nominal k_x of 6 m^{-1} to ensure that adequate design margin exists for the selected pole width.

4. An assessment of the impact on the ring impedance and the addition in the cost estimate of the required two new vacuum transitions should be completed.

5. A subproject plan with cost estimate and schedule to reengineer and fabricate an upgrade to the protein crystallography carbon filter assembly should be completed.

6. A development plan for dealing with internal tuning techniques for the wiggler should be determined to avoid delaying the schedule of installation should such tuning be necessary.

7. The schedule for the Internal Option scenario needs to be updated and reviewed with regard to all of the above revised estimates as well as including any required shutdown restrictions and planning requirements.

Action Item Follow-up 13 December 2002

On 13 December 2002 the W11 project team met with the chair of the Committee and ALS Management to provide an update on the project's response to the seven action items listed in this report. This section will summarize the status presented at that time.

Action Item 1: Make/Buy Analysis: The project team reexamined the two options for obtaining the wiggler. The external option consists of the procurement of a complete wiggler system and an internally supervised vacuum chamber and chamber support. The internal option consists of a sole source procurement of glued magnetic assemblies from Sumitomo and the procurement/fabrication of the backing beams, support structure, and vacuum chamber based on using the existing W16 design where possible with minimum modification. Risk, cost, schedule and allocation of internal resources were the criteria that the project used in its analysis. The project team considered the risk of procuring a complete wiggler system as being larger than the internal option as they have less experience with such a scheme. After a reexamination of the costs no strong differential was found between the internal and external options. A reexamination of the projected schedule for each option indicated a four-month preference for the internal approach. According to the project team the external option would demand more effort from resources that are already oversubscribed. The project team recommended pursuing the internal option and ALS management concurred.

Action Item 2: Refining Cost Estimate: The project team refined the cost estimates for both the internal and external options with particular emphasis on the internal option. As was requested by the action item, a number of vendor budgetary estimates were obtained. Individual line item contingencies were adjusted as deemed appropriate for the basis of estimate for the specific item. The total estimated cost for the internal option remained essentially unchanged (+1.2%), and the external option decreased slightly (-3%). All of the items requested in the action item were presented.

Action Item 3: Roll-off Simulation: An additional roll-off simulation 125% above the nominal k_x= 6.3 m^{-1} was performed and presented. This simulation of k_x= 8 m^{-1} showed no effect on either the dynamic or momentum aperture giving confidence that there is adequate design margin.

Action Item 4: Ring Impedance: The vacuum chamber design that was estimated included appropriate transition pieces. The impedance and resistive wall instabilities were reexamined and presented showing that the chamber as conceived should not degrade performance of the storage ring.

Action Item 5: Carbon Filter Subproject: The carbon filter approach was presented and a detailed cost and schedule estimate for its development and fabrication. The design employs an opposing carbon ring to balance the stresses on the copper material to which the carbon filter is being brazed. The design approach minimizes stress on the carbon. It appears that the approach will be less likely to suffer the same type of cracking that occurred in the Cornell devices. The sub-project approach appears well thought out and conservative allowing three prototypes prior to the fabrication of the final device. The total effort is estimated at being ~$100k and requiring approximately ten months from start of the development to installation.

Action Item 6: Internal Magnetic Tuning Techniques: The project team presented an approach for allowing the adjustment of the internal trajectory of the wiggler in order that the overlap between the laser and electron beams can be properly maintained. The approach is very straightforward and has been demonstrated on other devices throughout the world as very effective. The pole assemblies will be mounted with shim stock spacers (0.25 mm) when mounted onto the magnetic structure adapter plates. This will allow the local adjustment of the magnetic field of a pole by removing the shim spacer entirely or replacing it with a thinner spacer. This will locally increase the gap of the wiggler but will not decrease the clearances associated with the vacuum chamber or increase the achievable minimum gap. The magnetic signature of this tuning scheme is very favorable. It is principally a steering adjustment confined to the single pole pair being adjusted. No scheme has yet been developed for tuning the *y* trajectory (B_x error adjustment. The revised cost estimate included effort and time for the development of the tuning and measurement approaches.

Comment: The project team will need to develop both the tuning and measurement approach for wiggler cross-field, B_x.

Action Item 7: Schedule Reassessment: The schedule for the internal and external options were reexamined. The revised schedule for the internal option has the wiggler ready for installation by 24 November 2003, two months later than was presented in the review.